

Generating Novel Ideas: Fluency Performance in High-functioning and Learning Disabled Individuals with Autism

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Tasks of fluency tap the ability to generate multiple responses spontaneously following a single cue or instruction. The present study compared the fluency performance of subjects with autism and clinical control subjects at two different levels of ability (high-functioning subjects with a verbal IQ of 76 or greater, and globally learning disabled subjects with a verbal IQ of 74 or below). A battery of tasks was employed to assess subjects' word fluency (for letters and semantic categories), ideational fluency (for uses of objects and interpretations of meaningless line drawings), and design fluency (for abstract meaningless designs). Subjects with autism showed reduced fluency for both the word and ideational fluency tasks, generating significantly fewer responses than the clinical control subjects. Results were particularly striking for the ideational fluency tasks. On these tasks, autistic subjects produced very low response totals, with the performance of the high-functioning subjects with autism equivalent to that of the learning disabled subjects with autism and significantly inferior to that of the learning disabled control individuals. In contrast, the results of the design fluency paradigm paint a different picture. This paradigm revealed no significant difference in the quantity of designs generated by the subjects with autism and the control subjects but a clear qualitative difference, with the autistic group producing significantly higher rates of disallowed and perseverative responses. Whilst the results of the word and ideational fluency tasks are suggested to support the hypothesis that individuals with autism are impaired in the generation of novel responses and behaviour, the results of the design fluency task are equally consistent with an impairment in the regulation of behaviour through inhibition and/or monitoring. The implications of these findings for the study of executive function abilities in autism are discussed.

Keywords: Asperger syndrome, autism, creativity, fluency, executive function.

Abbreviations: BPVS: British Picture Vocabulary Scale; HFA: high-functioning individuals with autism; HFC: high-functioning control subjects; LDA: globally learning disabled individuals with autism; LDC: globally learning disabled control subjects; RCPM: Raven's Coloured Progressive Matrices; VMA: verbal mental age.

Introduction

Recent years have seen considerable speculation about the role that deficits in so-called executive function abilities play in the cognitive profile of autism. Executive function abilities cover a wide range of skills that are necessary for the conscious control of action when routine actions are inappropriate, insufficient, or unavailable because the situation is, in at least some respects, novel (Shallice & Burgess, 1991; Stuss & Benson, 1986). Several studies have assessed the ability of people with autism to regulate conscious volitional behaviour appropriately through planning, monitoring, the inhibition of prepotent behaviour, and the regulation of attention (e.g. Hughes &

Russell, 1993; Hughes, Russell, & Robbins, 1994; Ozonoff, Pennington, & Rogers, 1991; Prior & Hoffman, 1990; Turner, 1996). These studies have consistently demonstrated impairments in the regulation of thought and action in both high-functioning and learning disabled individuals with autism relative to age and ability matched control individuals. However, there has been little study of the ability to actually generate or initiate an appropriate idea, line of behaviour, or response. Yet when executive control of behaviour is required, the capacity to generate a new idea or line of behaviour is a critical ability without which spontaneous volitional behaviour may not get off the ground.

There are several reasons to think that people with autism might have serious and significant impairments in their capacity to generate novel ideas and behaviours spontaneously. Such an impairment would be consistent with the lack of spontaneity and initiative often described in autism (e.g. Bailey, Philips, & Rutter, 1996; Harris, 1993), the poverty of speech and action that is reported

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for some autistic individuals (Dykens, Volkmar, & Glick, 1991; Rumsey, Andreason, & Rapoport, 1986; Rumsey, Rapoport, & Sceery, 1985), and the well-documented failure of autistic children to engage in pretence (e.g. Baron-Cohen, 1987; Jarrold, Boucher, & Smith, 1996). Moreover, such an impairment may also be consistent with the high rate of repetitive behaviour that is observed in autism and the characteristic avoidance and dislike of change and things that are new or unfamiliar (see Turner, 1997). Indeed, an impaired capacity to generate novel ideas and behaviour may explain why a lack of imaginative activity and repetition are so closely associated in autism that they are best described as two sides of the same coin (Wing & Gould, 1979).

If individuals with autism have an impaired capacity to generate novel responses we must predict that they will perform poorly on experimental tasks that provide few or no cues to guide responding. Moreover, a generativity account would predict that this deficit would be particularly severe on tasks that require the subject to go beyond stored knowledge and generate truly novel and imaginative responses. Traditionally, the ability to generate and produce novel responses has been studied in fluency tasks in which subjects are asked to generate multiple responses to a single cue, stimulus, or prompt. In the most commonly used of the fluency tasks, the word fluency task (e.g. Benton, 1968; Lezak, 1995), subjects are required to produce as many words as they can that begin with a given letter, or belong to a given semantic category. Although this task is one of generativity in the sense that it requires subjects to produce many different responses to a single cue, it does not require the subject go beyond their knowledge and generate new and imaginative responses, or interpret the cue provided in a new or unusual manner. Rather, this task simply requires the subject to trawl their lexicon and retrieve suitable exemplars of the given category. Although it is not necessary to generate responses *de novo* on this task, it has been noted that successful performance on this task may depend on the ability to produce clusters of related responses (Estes, 1974; Raskin, Sliwinski, & Borod, 1992). In this way, it may be that in order to be maximally efficient subjects need to generate and adopt a strategy of self-cueing to produce a good score.

Tests of ideational fluency differ from tasks of word fluency in that they tap the ability to generate new and imaginative responses in addition to the ability to access stored knowledge. In the typical Uses of Objects paradigm (e.g. Guilford, Christensen, Merrifield, & Wilson, 1978, cited in Lezak, 1995; Wallach & Kogan, 1965), the subject is asked to name as many possible uses of a given object (e.g. a newspaper) in a certain time period. In this situation, it is possible to produce either common uses of the object (e.g. read it, use it to start a fire), or highly imaginative suggestions (e.g. for use as wallpaper, to keep warm). Although both types of response are correct, it is only the latter class of response that requires the subject to be truly creative in the sense of looking at the situation from new perspectives and identifying new possibilities.

A third class of fluency task, the Design Fluency Task of Jones-Gotman and Milner (1977), places even greater demands upon the generative skills of the subject. In this task, subjects are asked to produce as many different

designs as they can in a specified time period, excluding common or well-known designs that depict an object or symbol. Stored knowledge is of little use in this task as all responses must be truly original.

If individuals with autism have an impairment in the capacity to generate novel ideas and behaviours, it would be predicted that they would be impaired on tasks of fluency. However, it is important to note that failure on any test of fluency is not an unequivocal sign of generativity impairment. Successful fluency performance requires that subjects produce multiple responses that are both appropriate and distinct from previous responses. Individuals will perform poorly if they are impaired at generating novel ideas or responses, but they will also perform poorly if they fail to inhibit reference to what they know to be the true and established function of the object (in the case of the Uses of Objects Task); if they fail to inhibit previous, and thus prepotent, responses; if they fail to shift their attention away from one feature or aspect of the stimulus or previous response; or if they are unable to monitor their responses to ensure that each is appropriate.

Although it is not possible to distinguish between these possibilities in absolute terms, the nature of fluency tasks does allow some attempt to be made to disentangle these hypotheses. If poor performance on the standard Uses of Objects paradigm is due to an impaired capacity to inhibit reference to the established conventional use of the object, it should be possible to demonstrate relatively intact performance when the target object is replaced with unfamiliar objects with no single established function. In contrast, a primary problem inhibiting prior responses would predict high rates of repeated responses, whilst a higher-level inhibitory problem leading to an inability to shift attention from one aspect of the stimulus or prompt would predict high rates of highly similar, or highly redundant, responses indicating that the subject was "stuck" in one line of thought, or one approach, to the problem. Finally, a primary problem in monitoring the accuracy and appropriateness of behaviour might be expected to lead to high rates of incorrect and inappropriate responses that fail to meet the rules of the task. In this way, the best clues to the origins of poor fluency performance can be gained by studying performance across multiple measures of fluency, and examining in detail the profile of responses that subjects produce. Only where subjects show a low rate overall response rate, with a low rate of error responses, is there clear and unequivocal evidence of a primary generativity impairment.

Relatively few studies have explored the fluency performance of individuals with autism. Three studies have used tasks of word fluency paradigm to assess generative naming in high-functioning individuals with autism, producing a conflicting pattern of results. One study has reported impaired letter fluency (Rumsey & Hamburger, 1988), one study has reported impaired category fluency (Minshe, Goldstein, Muenz, & Payton, 1992), and one study has failed to show deficits on either category or letter fluency tasks in subjects with autism, relative to age and ability matched normal control subjects (Minshe, Goldstein, & Siegel, 1995). Two studies have explored word fluency in low-ability autistic and control groups, reporting no group differences for category (Boucher,

1988), nor letter (Scott & Baron-Cohen, 1996), fluency. None of these studies has reported either the profile of error responses produced by subjects, or the extent to which response sequences are clustered semantically or phonemically.

Boucher's (1988) study is particularly interesting as it included a further uncued test of word fluency. In this task, subjects were simply asked to think of as many miscellaneous words as they could in 60 seconds (subjects were instructed to name "as many words as you can think of, any words at all"). The children with autism performed very poorly on this task, generating significantly fewer words than the age and ability matched control subjects. As this task provides no cue to identify and define the set of possible responses, it places considerable demands on the individual's ability to develop an appropriate approach to an unusual and unconstrained problem. Subjects must generate a strategy through which responses can be produced (even if this strategy is simply naming all objects in the room). However, as this task does not require subjects to go beyond stored knowledge and generate imaginative responses, it remains qualitatively different to tasks of ideational fluency.

Only two studies have explored ideational fluency in subjects with autism and control subjects. Scott and Baron-Cohen (1996) asked subjects to generate as many uses of a brick as possible in a 2-minute period. Although these authors failed to find any difference between the subjects with autism and the control subjects in the number of responses produced, the relatively low ability of the subjects in general, and the control subjects in particular (mean verbal mental age [VMA] 4:6), leaves this result difficult to interpret. Lewis and Boucher (1991) explored the thematic relatedness of drawings produced by children with autism and control children in a series of testing sessions spread over the course of 12 months. Although this study revealed that the drawings produced by the subjects with autism were more highly similar than those produced by the control children, it is possible that the drawings of the children with autism were more constrained by what they felt able to draw, than what they were able to generate to draw.

Thus, although there is considerable reason to think that at least some subjects with autism may be poor at generating novel ideas, behaviour, and responses, there is little unequivocal evidence to support this hypothesis. Accordingly, the present experiment sought to compare the fluency performance of subjects with autism and clinical control subjects without autism when required to (1) retrieve multiple items of stored knowledge (letter and category fluency), and (2) generate new and imaginative responses (ideational and design fluency). Two tasks of ideational fluency were used: (1) a modified version of the Uses of Objects Task that utilised both common objects with an established function and junk objects chosen to have no clear or established function, and (2) the Pattern Meanings Task of Wallach and Kogan (1965) in which subjects are asked to produce multiple interpretations of a series of meaningless line drawings. Finally, the Design Fluency Task of Jones-Gotman and Milner (1977) was used to assess fluency performance when there is no cue to guide subjects' responses. In order to assess the possible impact of ability on generativity, this battery of fluency

tasks was administered to individuals with autism and clinical control subjects at two distinct levels of ability.

Method

Subjects

Four groups of subjects participated in this study: high-functioning subjects with autism (the HFA group), high-functioning control subjects (the HFC group), globally learning disabled (mentally retarded in North America) individuals with autism (the LDA group), and learning disabled control individuals (the LDC group). High-functioning subjects were defined as subjects with a verbal IQ of 76 or greater as assessed by the age-appropriate test from the Wechsler Intelligence Scales (Wechsler, 1981, 1992). Learning disabled subjects were defined as subjects with a verbal IQ of 74 or below.

Subjects with autism were recruited from Consultant Psychiatrists in East Anglia, National Autistic Society Establishments in the south of England, and East Anglian branches of the National Autistic Society. According to parental records, school files, or case notes, each of the autistic subjects had been diagnosed with "autism", "Asperger syndrome" or "autistic spectrum disorder" by a psychiatrist or paediatrician. Diagnosis was also verified at the time of study through the administration of two interviews designed by the author (Turner, 1996) and incorporating diagnostic criteria for autism as outlined in DSM-III-R (American Psychiatric Association, 1987). For each of the 44 experimental subjects, a diagnosis of autism was entirely consistent with the detailed account of the individual provided by his/her parents or carers.

The HFC subjects were recruited from the group of individuals referred to psychiatry services in Cambridge in the preceding 12 months for a nonautistic problem. The reasons for referral in this group were several and varied. They included attentional problems, anxiety, depression, and eating disorders. The LDC subjects were recruited from schools and services for children and adults with learning disabilities in Cambridgeshire. None of the control subjects were found to meet diagnostic criteria for autism on the basis of the interviews administered by the author.

All subjects were aged between 6 and 32 years and had a minimum verbal mental age of 4 years as assessed by the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Pintilie, 1982). The subject characteristics for each of these groups are presented in Table 1. Statistical comparisons showed there to be no significant differences between the subjects with autism and control subjects at either ability level in terms of chronological age, verbal mental age as assessed by the BPVS, verbal IQ as assessed by the Wechsler Intelligence Scales, or nonverbal IQ as assessed by Ravens Coloured Matrices (RCPM; Raven, 1986).

Procedure

Verbal fluency tasks.

(1) Letter Fluency (FAS) Task: The Letter Fluency (FAS) Task was the standard Controlled Word Association task of Benton (1968), in which subjects are required to generate as many different words as possible beginning with the letters F, A, and S. For each letter, subjects were given 60 seconds in which to generate "as many different words" as possible. Subjects were instructed not to use proper nouns, nor simply to repeat the same word with different endings.

Table 1
Subject Characteristics

	<i>N</i> Male:Female	Age ^a Mean (<i>SD</i>)	BPVS MA ^a Mean (<i>SD</i>)	WAIS/WISC verbal IQ Mean (<i>SD</i>)	RCPM nonverbal IQ Mean (<i>SD</i>)
HFA	22 19:3	12-0 (5-4)	11-6 (3-8)	100 (22.3)	108 (20.0)
HFC	21 18:3	11-11 (4-5)	12-4 (4-7)	101 (17.8)	110 (12.1)
LDA	22 19:3	14-0 (7-2)	6-6 (2-5)	60 (9.6)	88 (22.4)
LDC	22 16:6	12-10 (6-5)	7-2 (2-4)	59 (5.6)	79 (12.7)

^a Age and mental age in years-months.

Because the Letter Fluency Task presupposes some spelling ability, an informal check was made on subjects' understanding of how words were spelled. Subjects were first asked what letter (or sound) their name began with. They were then asked to name another word that began with the letter (or sound), and one word that began with three further letters. One HFA subject, five LDA subjects, and nine LDC subjects failed one or more elements of this pre-test and were excluded from the Letter Fluency Task. There were no differences between the revised autistic and control subject groups at either ability level in terms of chronological age, verbal mental age, verbal IQ, or nonverbal IQ.

(2) Category Fluency Task: A second task was used to assess word fluency for semantic categories. Three categories were used: animals, foods, and countries. As for the Letter Fluency Task, subjects were given 60 seconds in which to generate as many words as possible belonging to each category. It was emphasised that subjects should produce as many different words as possible without repeating the same word twice.

Ideational fluency tasks.

(1) Uses of Objects Task: This task began with an example as the experimenter asked the subject, "How could we use a newspaper? Tell me something useful that we could do with it?" Any appropriate suggestion made by the child was reinforced. Examples like "you could use a newspaper to start a fire", "you could roll it up and swat flies with it", and "you could use it to wrap a present" were provided by the experimenter as necessary and the subjects was encouraged to continue "brainstorming" similar examples.

Subjects were then asked to generate as many uses as they could for six different objects. Three of these objects had clear functions (a brick, a pencil, and a mug) and three were junk objects chosen to have no clear or established conventional function (a piece of plain navy blue gaberdine measuring 110 by 40 cm, a 50 cm length of dowelling, and a piece of clothing elastic 1 m long). The former items shall be referred to as the "conventional items" and the latter objects will be referred as the "nonconventional" items.

The order in which the conventional and nonconventional items were presented was counterbalanced across subjects, but within each category, the three items were presented in a fixed order. For each of the conventional items the experimenter gave two examples, one in line with the objects' established function (e.g. "you could use a pencil to write with"), and one that was imaginative (e.g. "you could use a pencil as a bookmark to keep your place in a book"). For the nonconventional items the experimenter gave one imaginative example per item (e.g. "you could use the stick to turn the television on and off if you couldn't reach the controls"). After the examples were provided subjects were instructed to "tell me all the other ways in which

you think a [object] could be useful". The subject was given 2½ minutes in which to think of as many uses for each object as they could. The experimenter praised and encouraged all subjects. If the subject was silent for more than around 15 seconds they were prompted to keep trying with comments such as "Keep thinking. How else could a [object] be useful?".

(2) Pattern Meanings Task: Six meaningless line drawings (taken from Wallach & Kogan, 1965) printed on individual 6 × 4 in cards were used as the stimuli for this task (see the Appendix). One served as a practice stimulus and the remaining five were test stimuli.

Subjects were shown the practice stimuli and asked "tell me what this could be?" Any appropriate response was praised and the subject was encouraged to continue to think of things that the pattern looked like. The experimenter also made suggestions such as "a hedgehog", "someone with spiky hair", "sparks from a fire cracker" and "a brush". Subjects were then shown the test stimuli one at a time and asked to think of as many different things as possible that each could be. Subjects were allowed to turn the cards around and view them from all orientations. For each item, subjects were given 2½ minutes to provide responses. The experimenter praised the subject's responses and encouraged the subject to continue responding after any silence of 15 seconds or more.

Design fluency task. The task was administered according to the procedure described by Jones-Gotman and Milner (1977). The "free" condition was always administered first and immediately followed by the "fixed", or four-line, condition. In the free condition, subjects were given 5 minutes to produce as many different designs as they could. It was explained that these designs had to be designs that were "made up" by the subject and that drawings of real, or nameable, objects or scribbles were not allowed. The experimenter demonstrated the task by drawing and discussing two allowable designs, and two designs that broke the rules of the task. Subjects were warned if they produced drawings of nameable objects or scribbles. If subjects produced three or more highly similar drawings they were also reminded to produce as many *different* patterns as they could. Whilst Jones-Gotman and Milner gave these warnings only once each, they were used up to three times each in the present procedure.

In the fixed condition, subjects were given 4 minutes in which to produce as many different designs as they could that were comprised of exactly four distinct lines. The experimenter explained the task further by drawing and discussing two allowable and two prohibited designs. It was emphasised that a line was counted as a single line so long as it did not include a sharp corner. Subjects were praised for allowable patterns. If subjects produced responses that broke the rules of the task they were warned in the same manner as for the free condition.

Measures and statistical analyses. For each of the tasks the main measures of performance were (1) the total number of responses produced, and (2) the percentage of total responses that were disallowed because they broke the rules of the task (error responses). In the word fluency tasks, error responses were defined as responses that were inappropriate, or repetitions of earlier responses. For all other tasks responses were classed as inappropriate/incorrect responses, repetitions of previous responses, or redundant responses. A redundant response was defined as a response that varied from a previous response only in terms of one minor element or feature of the response (e.g. suggesting that a brick may be used to build a garage, then a shed or a factory etc.; or producing designs that differed only in terms of rotation or position of one element of the design).

Additional measures were also used to assess performance on specific tests. Word fluency performance was also scored in terms of whether or not responses formed part of a semantic or phonemic cluster. A semantic cluster was coded if two or more successive items belonged to the same semantic category. In the case of the Letter Fluency Task, two responses were coded as belonging to a semantic cluster if they formed part of some broad category such as foods or animals, or any subordinate category such as fruits or household pets. In contrast, responses in the Category Fluency Task had to belong to the same subordinate category if they were to be rated as belonging to the same semantic cluster. A phonemic cluster was rated if two or more successive words began with the same first and second phonemes (e.g. sleep followed by slow), or if they rhymed (goose followed by moose). Cluster usage was calculated as the percentage of total responses that formed part of a semantic or phonemic cluster. This measure was calculated separately for semantic and phonemic clusters in each task.

Ideational fluency performance was also assessed in terms of the proportion of total responses that were judged to be highly imaginative. This was defined as a highly interpretative response that takes account of all of the characteristics of the stimulus in an imaginative, but plausible, fashion.

An independent second rater, who was blind to subjects' diagnosis and ability, scored the responses of 40 subjects (10 subjects chosen at random from each group) for (1) cluster usage in the word fluency task, (2) highly imaginative responses in the ideational fluency tasks, and (3) redundant responses in the ideational and design fluency tasks. Overall percentage agreement was in excess of 85% for all measures and all tasks, and all kappa values were in excess of .70, indicating satisfactory agreement. Discrepancies were resolved through discussion between the raters.

Results

Word Fluency

Total number of responses. A three-way repeated measures ANOVA was used to explore the effects of Group (autism, control), Ability (high-functioning, learning disabled) and Task (FAS, Category Fluency) on the total number of responses produced. This analysis yielded significant main effects of Group [$F(1,67) = 4.96, p < .05$] and Ability [$F(1,67) = 21.99, p < .001$], reflecting performance advantages for control, relative to autistic, and high-functioning, relative to learning disabled, subjects (see Fig. 1). A significant main effect of Task [$F(1,67) = 159.2, p < .001$] and a significant Ability \times Task interaction [$F(1,67) = 7.18, p < .01$] were also obtained. Simple effects tests revealed that this interaction could be attributed to a greater effect of Task for the high-

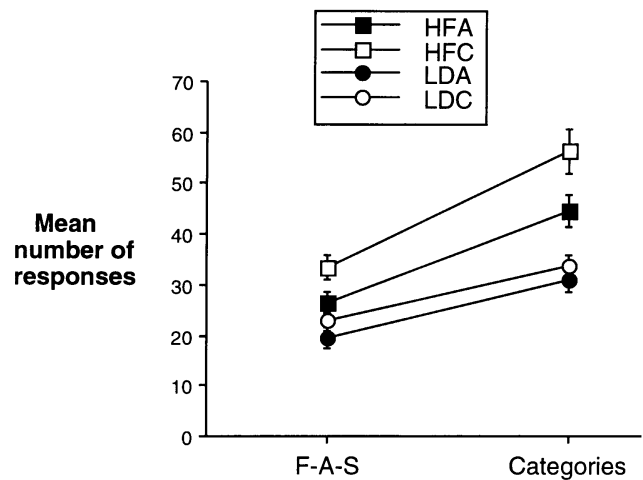


Figure 1. Total number of responses produced in the word fluency tasks.

functioning [$F(1,67) = 144.13, p < .001$], relative to the learning disabled [$F(1,67) = 42.10, p < .001$], subjects. In contrast, the Group \times Ability [$F(1,67) = 1.13, p = .29$], Group \times Task [$F(1,67) = 0.41, p = .52$], and the three-way interaction terms [$F(1,67) = 0.55, p = .46$] were all nonsignificant.

Error responses. Table 2 presents the means and standard errors for the proportion of incorrect responses and repetitive errors that occurred in each test, along with the results of Mann-Whitney *U* test comparisons. This table shows that there is no difference in the proportion of error responses produced by autistic and matched control subjects for either class of error.

Phonemic and semantic clusters. For each task and each subject, the percentage of responses that formed part of a phonemic or a semantic cluster was calculated in the manner described above. Table 3 shows that all groups have a tendency to use phonemic clustering in the FAS task and semantic clustering in the Category Fluency Task. A three-way repeated measures ANOVA was used to compare the proportion of responses that formed part of a phonemic cluster in both the Letter and the Category Fluency Tasks. This analysis confirmed that there was a significant main effect of Task [$F(1,67) = 92.08, p < .001$], but revealed no significant main effect of Group [$F(1,67) = 1.37, p = .25$] or Ability [$F(1,67) = 0.004, p = .95$], and no significant interaction terms between these factors.

A comparable ANOVA procedure for the semantic cluster data revealed significant main effects of Group [$F(1,67) = 6.05, p < .05$] and Task [$F(1,67) = 538.02, p < .001$], but no significant main effect of Ability [$F(1,67) = 2.21, p = .14$]. The Ability \times Task interaction was also significant [$F(1,67) = 10.75, p < .01$]. Simple effects tests revealed that this interaction was attributable to significantly better performance in the high-functioning relative to the learning disabled subjects for the Category [$F(1,67) = 10.37, p < .01$], but not the FAS [$F(1,67) = 1.99, p = .16$], task. The remaining interaction terms were all nonsignificant.

Can differences in cluster use explain the group differences? Analysis of covariance was used to compare the

Table 2
Percentage of Responses Classified as Errors

	HFA Mean (SEM)	HFC Mean (SEM)	LDA Mean (SEM)	LDC Mean (SEM)	Mann-Whitney <i>U</i> test results ^a
Word fluency					
Incorrect responses	6.73 (1.17)	6.16 (1.11)	16.40 (3.71)	13.11 (2.86)	HFA = HFC LDA = LDC
Repetitions	2.64 (0.39)	2.86 (0.83)	3.66 (1.11)	2.81 (0.65)	HFA = HFC LDA = LDC
Ideational fluency					
Inappropriate responses	14.95 (2.55)	4.15 (0.74)	23.93 (2.85)	10.59 (1.36)	<i>HFA > HFC: U = 101.5, z = -3.15**</i> <i>LDA > LDC: U = 90.0, z = -3.57***</i>
Repetitions	3.01 (0.69)	1.51 (0.44)	11.79 (2.64)	4.39 (0.78)	HFA = HFC <i>LDA > LDC: U = 124.5, z = -2.76**</i>
Redundant responses	21.72 (2.39)	13.09 (2.19)	31.67 (3.15)	31.22 (1.96)	<i>HFA > HFC: U = 120.0, z = -2.69**</i> LDA = LDC
Design fluency					
Incorrect designs	12.71 (2.64)	4.58 (0.98)	42.34 (6.22)	16.17 (2.30)	<i>HFA > HFC: U = 112.0, z = -2.89**</i> <i>LDA > LDC: U = 93.5, z = -3.49***</i>
Repetitions	5.56 (2.78)	0.53 (0.26)	21.52 (5.29)	4.13 (1.31)	<i>HFA > HFC: U = 146.5, z = -2.41**</i> <i>LDA > LDC: U = 143.5, z = -2.41**</i>
Redundant designs	11.04 (1.98)	2.55 (0.83)	15.95 (2.78)	6.24 (1.58)	<i>HFA > HFC: U = 95.5, z = -3.36***</i> <i>LDA > LDC: U = 94.0, z = -3.48***</i>

^a Italicised results are significant.

** $p < .01$; *** $p < .001$.

Table 3
Percentage of Word Fluency Responses Forming Part of a Cluster

	HFA Mean (SEM)	HFC Mean (SEM)	LDA Mean (SEM)	LDC Mean (SEM)
Phonemic cluster				
FAS	33.68 (4.27)	34.20 (2.97)	30.24 (5.42)	43.69 (5.96)
Categories	17.79 (2.13)	16.75 (2.31)	11.76 (2.23)	14.61 (1.89)
Semantic cluster				
FAS	13.59 (2.20)	17.05 (1.74)	18.06 (3.78)	23.34 (4.09)
Categories	68.17 (2.84)	75.62 (2.37)	60.70 (3.74)	65.05 (3.06)

total number of responses produced by the subjects with autism and control subjects in each task, whilst controlling for the proportion of those responses that were part of a semantic or a phonemic cluster. Considering the FAS task first, controlling for phonemic clustering produced a significant effect of Ability [$F(1,67) = 15.48, p < .001$], but no significant effect of Group [$F(1,67) = 3.68, p = .07$], and no Group \times Ability interaction [$F(1,67) = 1.32, p = .25$]. In contrast, after controlling for semantic cluster use, effects of both Group [$F(1,67) = 5.61, p < .05$] and Ability [$F(1,67) = 12.45, p < .001$] remained significant whereas the Group \times Ability interaction term was nonsignificant [$F(1,79) = 0.57, p = .45$]. The opposite pattern of results was found for the Category Fluency Task. When controlling for the effects of phonemic cluster usage, there were significant effects of both Group [$F(1,79) = 4.84, p < .05$] and Ability [$F(1,79) = 24.73, p < .001$], but no Group \times Ability interaction [$F(1,79) = 2.22, p = .14$]. However, when controlling for extent of semantic cluster usage, the effect of Group was rendered nonsignificant [$F(1,79) = 3.53, p = .06$], along with the Group \times Ability interaction [$F(1,79) = 2.07, p = .15$],

such that only the effect of Ability [$F(1,79) = 26.99, p < .001$] remained significant.

This pattern of results is particularly striking. The fact that controlling for the degree of appropriate cluster usage removes group differences on both the FAS and the Category Fluency Tasks is consistent with the suggestion that the poorer performance of the subjects with autism may be attributable to a failure to exploit the phonemic and semantic relatedness of words to improve performance, rather than an inability to produce multiple responses per se.

Ideational Fluency

Number of responses. The results for the Pattern Meanings Task and the Uses of Objects Task were analysed with separate ANOVA procedures. Table 4 presents the results of these analyses. They demonstrate that across both tasks, the performance of the subjects with autism is significantly poorer than that of the control

Table 4
ANOVA Results for the Ideational Fluency Tasks

Variable	Task	Effect ^a
Total number of responses	Pattern Meanings	<i>Group: $F(1,83) = 14.02, p < .001$</i> <i>Ability: $F(1,83) = 0.81, p = .37$</i> <i>Group × Ability: $F(1,83) = 0.32, p = .57$</i>
	Use of Objects	<i>Group: $F(1,83) = 27.21, p < .001$</i> <i>Ability: $F(1,83) = 2.70, p = .10$</i> <i>Group × Ability: $F(1,83) = 0.46, p = .50$</i> <i>Item Type: $F(1,83) = 13.91, p < .001$</i> <i>Group × Item Type: $F(1,83) = 3.94, p = .05$</i> <i>Ability × Item Type: $F(1,83) = 4.07, p = .05$</i> <i>Group × Ability × Item Type: $F(1,83) = 1.58, p = .21$</i>
Proportion of highly imaginative responses	Pattern Meanings	<i>Group: $F(1,83) = 46.27, p < .001$</i> <i>Ability: $F(1,83) = 32.85, p < .001$</i> <i>Group × Ability: $F(1,83) = 4.92, p < .05$</i>
	Use of Objects	<i>Group: $F(1,83) = 36.17, p < .001$</i> <i>Ability: $F(1,83) = 17.02, p < .001$</i> <i>Group × Ability: $F(1,83) = 6.37, p < .05$</i> <i>Item Type: $F(1,83) = 30.64, p < .001$</i> <i>Group × Item Type: $F(1,83) = 6.36, p < .05$</i> <i>Ability × Item Type: $F(1,83) = 8.83, p < .01$</i> <i>Group × Ability × Item Type: $F(1,83) = 0.34, p = .56$</i>

^a Italicised effects are significant.

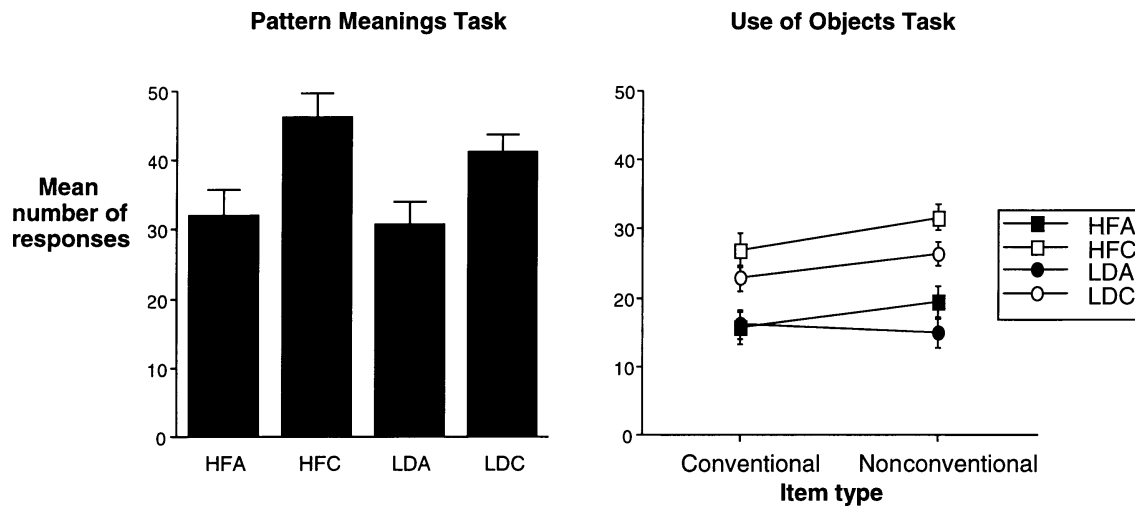


Figure 2. Number of responses produced in the ideational fluency tasks.

subjects (see Fig. 2). It is particularly notable that the number of responses produced by the HFA subjects is not just significantly fewer than the number produced by the HFC subjects, but also significantly fewer than the number of responses produced by the LDC subjects.

In addition, the ANOVA procedure for the Uses of Objects Task reveals a significant effect of Item Type and significant Group × Item Type and Ability × Item Type interactions. Simple effects tests show that the Group × Item Type interaction is attributable to a performance advantage for the nonconventional over the conventional items in the control subjects [$F(1,83) = 16.05, p < .001$], which is not seen in the subjects with autism [$F(1,83) = 1.54, p = .22$]. Similarly, the Ability × Item Type interaction is attributable to a significant advantage for the nonconventional over the conventional items for the

high-functioning [$F(1,83) = 16.23, p < .001$], but not the learning disabled [$F(1,83) = 1.49, p = .23$], subjects, and a significant effect of Ability for the nonconventional [$F(1,83) = 4.97, p < .05$], but not the conventional [$F(1,83) = 0.58, p = .45$], items.

Error responses. Table 2 presents the means and standard errors for the proportion of errors of each type, along with the results of Mann-Whitney *U* test comparisons. These analyses reveal that at both levels of ability, the subjects with autism produced significantly more inappropriate responses than the control individuals. In contrast, the same across-the-board differences were not observed for the proportion of responses classed as repeated or redundant. Although the LDA subjects displayed a greater proportion of repeated items than the LDC subjects, there was no difference between

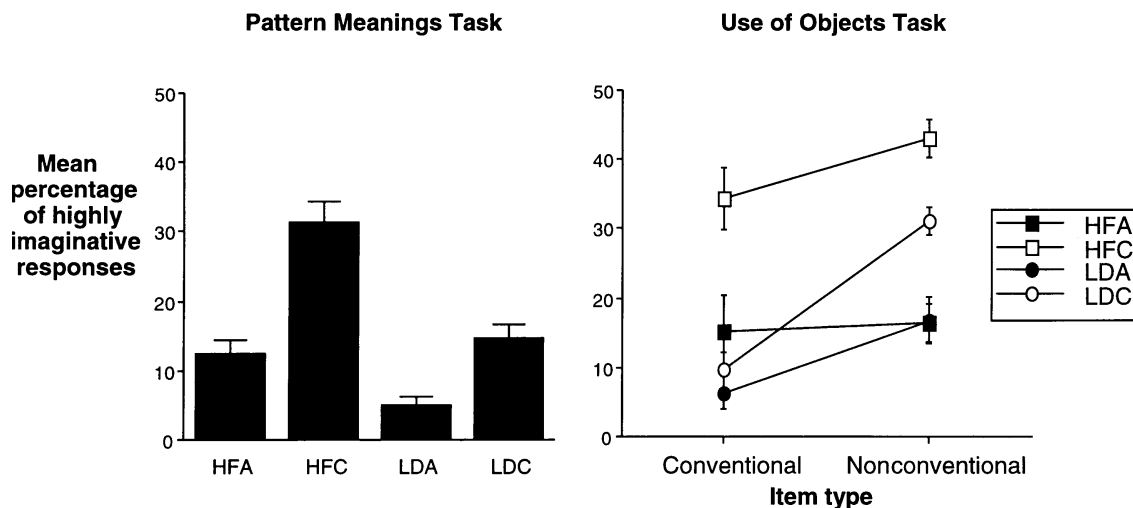


Figure 3. Percentage of responses rated as highly imaginative for the ideational fluency tasks.

these groups in the proportion of redundant responses produced. The opposite pattern of results was observed for the HFA, relative to the HFC, subjects.

Highly imaginative responses. Figure 3 displays the proportion of total responses rated as highly imaginative for the ideational fluency tasks. Table 4 shows the results of the ANOVA procedures for these data. Both analyses reveal highly significant performance advantages for control over autistic, and high-functioning over learning disabled, groups. In addition, the Group \times Ability interaction was significant in both analyses. For the Pattern Meanings results this interaction was attributable to a greater effect of Ability for the control subjects [$F(1,83) = 29.98, p < .001$], relative to the subjects with autism [$F(1,83) = 6.25, p < .05$], and a greater effect of Group for the high-functioning [$F(1,83) = 39.02, p < .001$], relative to the learning disabled [$F(1,83) = 10.64, p < .01$], subjects. Similarly, the significant Group \times Ability interaction for the Uses of Objects data was attributable to a significant effect of Ability for the control subjects [$F(1,83) = 20.93, p < .001$], but not the subjects with autism, [$F(1,83) = 1.30, p = .26$], and a greater effect of Group for the high-functioning [$F(1,83) = 35.22, p < .001$], relative to the learning disabled [$F(1,83) = 6.16, p < .05$], subjects. This pattern of results is particularly striking as it indicates that the higher ability of the HFA subjects offers these individuals little or no performance advantage over the significantly less able LDA subjects. In contrast, the high ability of the HFC subjects leads to substantially better performance than that achieved by the learning disabled control subjects.

Design Fluency

The total number of designs produced. A three-way repeated measures ANOVA failed to find any difference in the number of designs produced by the autistic and control subjects. The main effect of Group [$F(1,83) = 2.73, p = .10$], the Group \times Ability [$F(1,83) = 0.94, p = .34$], Group \times Condition [$F(1,83) = 3.11, p = .08$], and three-way interaction terms [$F(1,83) = 0.13, p = .72$] were all found to be nonsignificant.

In contrast, significant main effects of Ability [$F(1,83) = 4.47, p < .05$], Condition [$F(1,83) = 39.87, p < .001$], and a significant Ability \times Condition interaction [$F(1,83) = 4.78, p = .03$] were observed. Simple effects tests showed that the Ability \times Condition interaction was attributable to significantly better performance in the high-functioning, relative to the learning disabled, subjects for the fixed [$F(1,83) = 8.00, p < .01$], but not the free [$F(1,83) = 0.84, p = .36$], condition, and a greater effect of Condition for the high-functioning [$F(1,83) = 35.31, p < .001$], relative to the learning disabled [$F(1,83) = 8.63, p < .01$], subjects. This pattern of results indicates that the increased restrictions of the fixed condition lead to an improvement in performance in the high-functioning, but not the learning disabled, subjects (see Fig. 4).

Error responses. Table 2 presents the mean and standard error for the proportion of error responses of each type, along with the results of Mann-Whitney U test comparisons. These analyses show that at both levels of ability, the subjects with autism displayed significantly more errors of all classes than do the control subjects.

Subsequent analyses subtracted the total number of error responses produced by each subject from the total number of responses produced to give a novel output score for each subject. These data present a very different picture to that depicted by the total response data (see Fig. 5). A repeated measures ANOVA confirmed the fact that high rates of error scores in the autistic group were masking significant group differences in the number of novel and allowable designs that were produced. This analysis yielded significant main effects of Group [$F(1,83) = 37.75, p < .001$], Ability [$F(1,83) = 18.15, p < .001$], and Condition [$F(1,83) = 5.99, p < .05$], and significant Group \times Condition [$F(1,83) = 19.05, p < .001$] and Ability \times Condition [$F(1,83) = 6.36, p < .05$] interactions. Only the Group \times Ability interaction and the three-way interaction term remained nonsignificant. The significant Ability \times Condition interaction was due to significantly greater novel output scores in the fixed relative to the free condition for the high-functioning [$F(1,83) = 11.61, p < .001$], but not the learning disabled [$F(1,83) = 0.00, p = .96$], subjects. Similarly, the

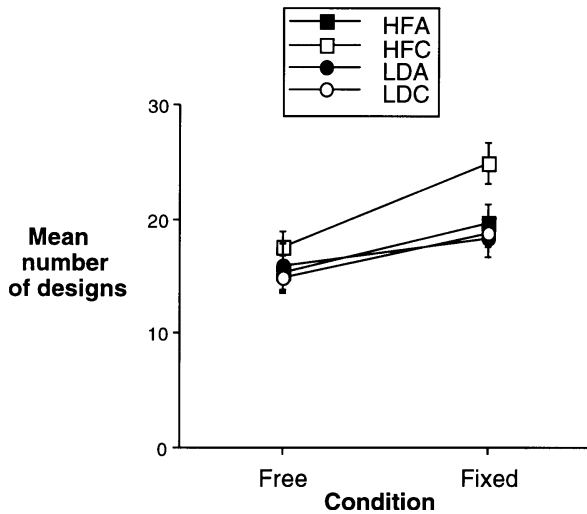


Figure 4. Total number of designs produced in the Design Fluency Task.

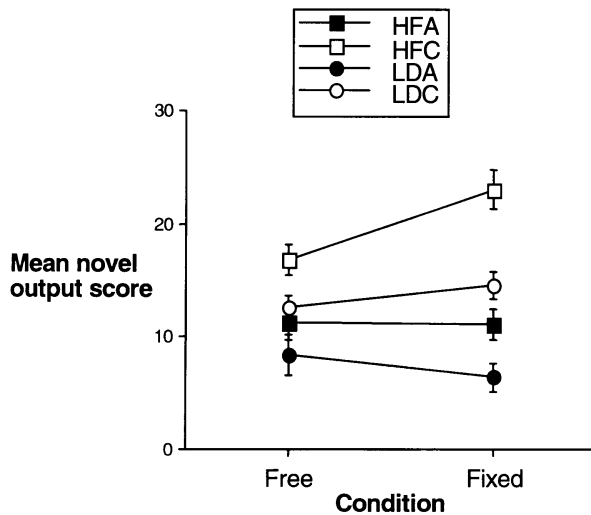


Figure 5. Novel output score for each condition of the Design Fluency Task.

Group \times Condition interaction was attributable to a significant effect of Condition for the control [$F(1,83) = 22.40, p < .001$], but not the autistic [$F(1,83) = 1.86, p = .18$], subjects, and a tendency for the performance advantage of the control subjects to be greater for the fixed [$F(1,83) = 56.64, p < .001$], relative to the free [$F(1,83) = 12.29, p < .001$] condition. This pattern of findings demonstrates that when only correct and allowable responses are considered, the facilitation of performance produced by the increased restrictions of the fixed condition is not just significantly greater for the high-functioning, relative to the learning disabled, subjects, but is also characteristic of the control subjects, relative to the subjects with autism.

The Relationship between Age, Ability, and Different Classes of Fluency Performance

An intercorrelation matrix was constructed to explore the relationship between subjects' age, verbal IQ, and

Table 5
Correlation Matrix Using Pearson Product-moment Correlation Coefficients

	Word fluency	Ideational fluency	Design fluency
Autism			
Age	-.08	-.06	.05
VIQ	.54*	.19	.32
Word fluency		.58**	.68**
Ideational fluency			.65**
Control			
Age	.59**	.16	.24
VIQ	.48**	.47*	.34
Word fluency		.76**	.75**
Ideational fluency			.72**

* $p < .05$; ** $p < .01$.

fluency performance. Composite scores for each of the three classes of fluency task were calculated by computing the total number of correct and allowable responses produced across all items and conditions within each class. Pearson product-moment correlation coefficients for this intercorrelation matrix are shown in Table 5.

Given the wide variation in age and ability of both subjects with autism and control subjects, there is remarkably little association between age, ability, and fluency performance. The significant correlations for word fluency performance with both age and verbal IQ are likely to reflect the simple fact that younger and less able individuals have smaller vocabularies than older and more able subjects.

However, Table 5 also shows that for both subjects with autism and control subjects there are significant intercorrelations between performance in each of the three classes of fluency task. The magnitude of these correlations is broadly similar for both autistic and control groups and suggests that the broad range of fluency tasks employed in this study tap some common ability.

Discussion

Although each of the three classes of fluency task reveals a different pattern of responding, the overall pattern of results is consistent with the hypothesis that individuals with autism are impaired in the ability to generate multiple novel responses following a single cue or instruction. Across all the fluency tasks employed, subjects with autism at two distinct levels of ability were found to display marked impairments relative to age and ability matched clinical control subjects.

The word fluency tasks showed clear evidence of reduced fluency in the autistic, relative to the control, groups at both levels of ability. However, there was no difference between the groups in the proportion of inappropriate or perseverative responses produced. At first glance, this pattern of results appears to suggest that individuals with autism have deficits on any relatively open-ended task that requires subjects to produce multiple responses to general cues. However, the data on the clustering of subjects' responses suggests that this deficit

can be explained by the fact that a smaller proportion of the responses produced by subjects with autism were clustered in groups of semantically or phonetically related words. Controlling for the use of semantic clustering was able to remove group differences in the Category Fluency Task, and controlling for the extent of phonemic clustering was able to remove group differences on the Letter Fluency Task. Moreover, it appeared that many of the control (and in particular the HFC) subjects actively adopted a self-cueing technique that was not readily observable in the subjects with autism. In this way, the reduced response clustering of the subjects with autism may reflect a failure to generate, or use, a strategy to improve performance, rather than a failure to produce or retrieve lexical items from memory. This conclusion is consistent with Boucher's (1988) finding that word fluency performance in autism is most disrupted when it is uncued and therefore dependent on the subjects' ability to generate a strategy with which to approach the task.

In line with the specific predictions of a generativity deficit hypothesis, the ideational fluency tasks demonstrated striking deficits in the ability of the subjects with autism to generate novel responses and ideas. These tasks showed that the subjects with autism generated very significantly fewer responses, and a significantly smaller proportion of highly imaginative responses, than did the control subjects. In particular, the performance of the high-functioning autistic group was remarkably poor, being almost indistinguishable from the LDA group, and significantly more impaired than the LDC group despite a difference in mean verbal IQ of over 40 points.

Considering the responses of individual subjects, the results are equally striking. On the Pattern Meanings Task, for example, 11 out of the 22 LDA subjects and 8 out of the 22 HFA subjects achieved fewer novel responses than any of the LDC subjects. Moreover, all of the LDA subjects, and 17 of the HFA subjects, scored below the LDC median. It is particularly notable that there was no significant correlation between age, IQ, and the number of total responses produced on the ideational fluency tasks. Many of the most able, and some of the oldest, HFA subjects were among the most impaired on these tasks. The only adult in this study to have held gainful employment was one of the three most impaired subjects on this task. After completing the Uses of Objects Task he commented that thinking of things "has always been my biggest problem". Similarly, the only two subjects with autism attending mainstream school were also among the most impaired on these tasks. These three subjects produced as few as one or two responses on some trials and failed to produce any responses that could be classed as "highly imaginative".

In contrast, the Design Fluency Task failed to provide clear-cut support for a generativity deficit in autism. Although the high-functioning control subjects experienced an almost paradoxical marked facilitation of performance moving from the free to the fixed condition that was not observed in the other groups, there was no significant difference between the total number of responses generated by the subjects with autism and control subjects in either condition.

The most notable feature of the autistic performance on the Design Fluency Task was the high rates of

inappropriate and repetitive responses produced. In both conditions and at both levels of ability, subjects with autism produced disproportionately high error rates (three to four times more than the control subjects, in comparison to just under twice as many in the ideational fluency tasks and roughly comparable numbers in the word fluency tasks), which masked significant differences in the underlying rate of correct and allowable responses between the subjects with autism and the controls. Although high rates of inappropriate and perseverative responding may follow from an impaired capacity to generate multiple novel responses, this profile of responding is also consistent with a primary impairment in the appropriate regulation of response behaviour in autism.

Given that the ideational and design fluency tasks share the common requirement that subjects produce multiple novel responses, it is surprising that the subjects with autism produced such different response profiles for the two classes of task. One possible explanation for this discrepancy may lie in the fact that the Design Fluency Task places greater demands on the systems responsible for monitoring and inhibiting behaviour than do the ideational fluency tasks. There are at least two reasons to think that this may be the case. First, monitoring the novelty and appropriateness of responses is likely to be a more complex process in the Design Fluency Task, which requires consideration of complex abstract stimuli that combine multiple elements. In contrast, most responses to the ideational fluency tasks are given as a single concept or idea. Second, the Design Fluency Task, unlike the other fluency tasks, does not demand that the subject fully formulates the idea behind each response before beginning to produce that response. Clearly, on tasks such as the Uses of Objects Task the subject must first begin by generating some idea in a full and complete way. However, subjects may complete the Design Fluency Task by beginning each design before they have fully formulated an idea, thus to some extent generating "on the go". It is possible that this approach is more likely to result in high rates of perseverative responding as the subject begins his or her response without stopping to plan the response fully, and therefore is more susceptible to "capture" by the salience of the previous response (or the motor programme that produced that response). In support of this possibility, two of the subjects with autism who produced very high rates of repetitions on the Design Fluency Task expressed frustration that they produced the same design many times over, yet they seemed unable to do anything to prevent this repetition.

The curious finding that high rates of repetitive responding in autism can be accompanied by some understanding of the inappropriateness of this responding is reminiscent of reports of patients with frontal lobe injuries who spontaneously describe their responding on tasks such as the Wisconsin Card Sort Task as incorrect but continue to perseverate on every trial (e.g. Milner, 1963). Similarly, the general tendency for the subjects with autism to produce high rates of repetitive and redundant responses is reminiscent of work by Uta Frith (1970, 1972) reporting high rates of repetitive and rule-bound responding in children with autism who were asked simply to produce sequences of coloured counters

or notes on a xylophone given two to four response choices. In each case, these findings have been interpreted as reflecting impairments in the inhibitory control of behaviour (see also C. D. Frith & Done, 1990).

Although speculative, this link with inhibition is echoed in other observations made during the testing of the subjects with autism. Just as a small number of subjects with autism appeared frustrated at repeating responses on the Design Fluency Task, four of the subjects with autism and two of the control subjects spontaneously volunteered that they were having difficulty with the ideational fluency tasks because they had one idea "stuck" in their head. Moreover, on the Pattern Meanings Task some subjects were able to give no more than one novel response per different view (or orientation) of the stimulus card. Although this profile of responding was not restricted to subjects with autism, it was most notable in the individuals with autism and rarely observed in the HFC individuals.

The fact that the results of the present study are consistent with both impaired generation and inhibition of behaviour is interesting, as these two abilities are, in a sense, two sides of the same coin. In an unprompted situation, the transition from one activity to a new line of action must involve both the cessation of the original activity and the generation of another. For this reason, tasks of generativity are by their very nature likely to be vulnerable to impairments of inhibition. Although there can be little doubt that many individuals with autism have inhibitory deficits, a simple explanation of the poor performance of people with autism in terms of impaired regulation or inhibition of behaviour is inadequate to account for the overall pattern of results obtained in the present study. Although high rates of inappropriate and repetitive responses were reported for the ideational and design fluency tasks, the very low levels of error responses produced on the word fluency task suggests there is no widespread or fundamental impairment of behavioural regulation in autism that could account for the reduced fluency of the subjects with autism. In contrast, the high correlation between the number of allowable responses generated in the different fluency tasks is consistent with the idea that the different tasks are all tapping a single common skill. It is notable that 10 subjects in the HFA group accounted for the bottom 6 scores across all ideational and design fluency tasks, with a core of 6 of these individuals attaining the bottom 6 scores for the majority of the fluency tasks. Similarly, the lowest scores across the fluency tasks for the LDA group were accounted for by 11 subjects. Moreover, many of these low-scoring subjects displayed a marked poverty of spontaneous speech and action in everyday life that would be consistent with a reduced capacity to generate multiple novel ideas.

The relationship between the capacity to generate novel appropriate behaviour and the capacity to inhibit prior and inappropriate behaviour is important to any full consideration of executive function capacity. Although the majority of the literature on executive function ability in autism has focused on those skills that are important in the *regulation* of volitional action, the ability to *generate* novel responses, ideas, and action plans must be a key component of the executive system. In the SAS model of

Norman and Shallice (1986; Shallice, 1988), for example, the ability to generate a novel course of action is one of the chief duties and responsibilities of the SAS, or executive, system. Norman and Shallice predict that any major disruption to the functioning of the SAS system will seriously impair the capacity to generate novel behaviour and result in substantial and pervasive deficits in cognitive and adaptive functioning.

Clearly, an impaired capacity to generate novel ideas and action plans would be expected to lead to severely compromised spontaneous behaviour that is restricted in scope, lacking in originality and variability, and characterised by repetition. In support of this prediction there is considerable evidence that individuals with autism lack initiative and imagination (e.g. Bailey et al., 1996; Harris, 1993), and have restricted behavioural repertoires (Lovaas, Schreibman, & Koegel, 1974) characterised by repetition and invariance (e.g. Turner, 1997; Wing & Gould, 1979). Recent evidence has also identified a correlational link between performance on ideational and design fluency tasks and the display of repetitive behaviour in children and adults with autism such that poor fluency performance is associated with high rates of certain classes of repetitive behaviour (Turner, 1997).

However, an impaired capacity to generate novel behaviour would be expected to disrupt not only spontaneous behaviour, but also the execution of routine behaviour where unusual or varied circumstances are encountered, or some form of trouble-shooting is required. Although dealing with unexpected circumstances may not require the generation of new behaviour, it is likely to necessitate the generation of new hypotheses, and the restructuring of well-learned behaviours. In everyday situations, this type of trouble-shooting or modification of established behaviour may frequently be required. For example, it is easy to see how in even familiar social situations the fact that different people have different beliefs and behave in different ways may place considerable demands on the individuals' capacity to generate alternative hypotheses about behaviour and improvise accordingly. In this sense, everyday mentalising ability may involve not just the ability to appreciate that others have mental states that are independent of one's own, but to hypothesise about what the consequence of having that mental state would be by combining knowledge and experience in a novel way. In this way, the study of generativity may be important for more than what it can say about the generation of novel behaviour and ideas in autism. An understanding of the ability to generate novel behaviours and ideas may have implications for the ability of people with autism to control, regulate, and modify their behaviour in all areas of functioning.

Broadening the study of executive function abilities in autism to include the ability to generate spontaneous volitional activity may allow us to make important advances in our understanding of the cognitive and also the symptom profile that characterises autism. In particular, there is considerable scope for further research exploring the influence of task parameters on generativity performance in open-ended tasks. It is likely that factors such as the usefulness of the cue in generating multiple responses, the extent to which the task can be done on the

basis of stored knowledge, the requirement to be creative, and the nature and modality of the response required, all play a role in the extent to which the task is vulnerable to generativity or other executive impairments. In this way, further study may identify whether, and indeed when, the fluency deficits shown by individuals with autism are attributable to impairments in the generation, inhibition, or monitoring of responses. In turn, this research may provide the clinical literature with valuable clues to those situations and techniques that can aid and improve the functioning of people with autism at both the cognitive and the behavioural level.

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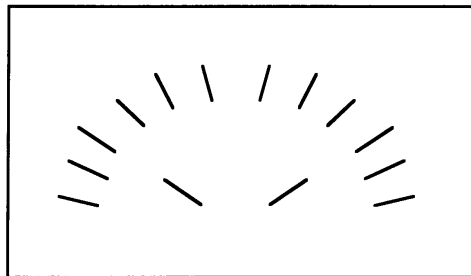
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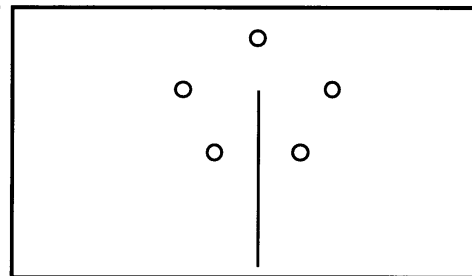
Manuscript accepted 6 April 1998

Appendix

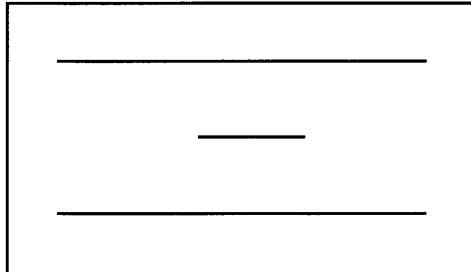
Patterns Used In the Pattern Meanings Task (Taken from Wallach & Kogan, 1965)



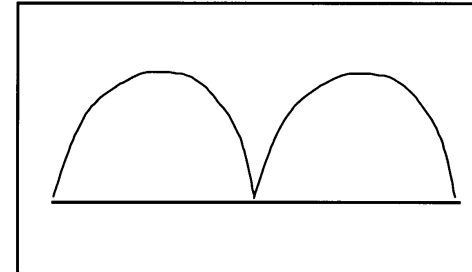
Practice



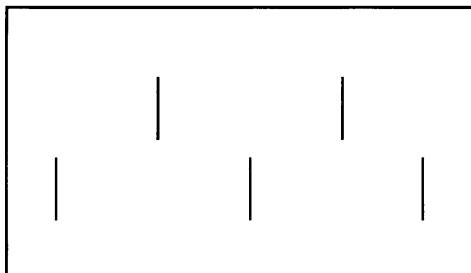
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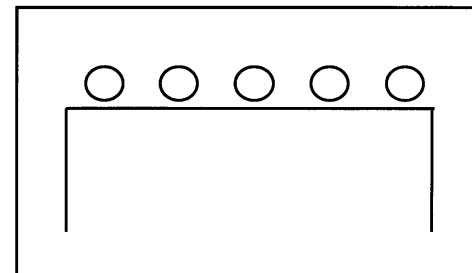
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3



4



5